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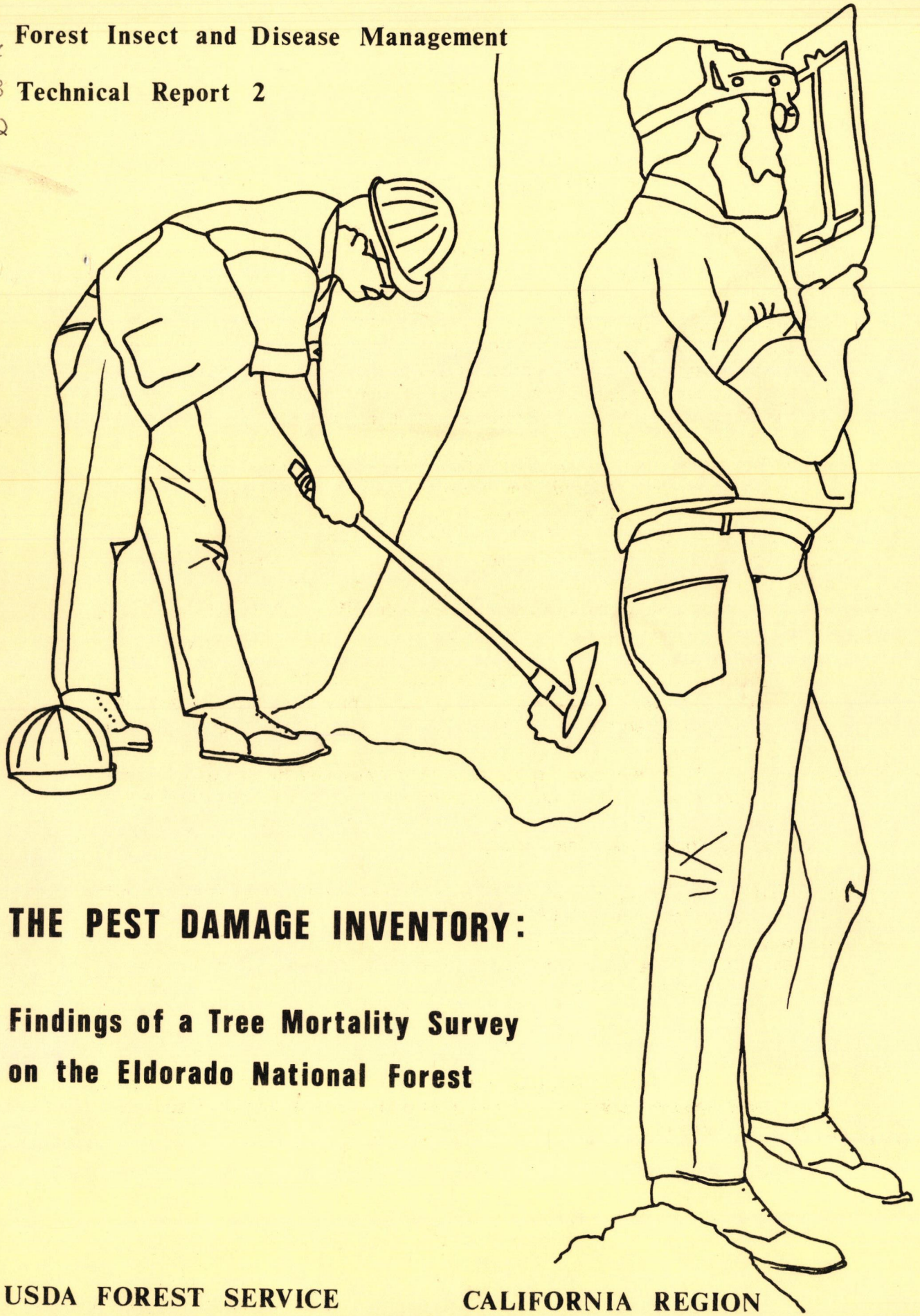
Forest Insect and Disease Management

Technical Report 2



THE PEST DAMAGE INVENTORY:

Findings of a Tree Mortality Survey on the Eldorado National Forest

USDA FOREST SERVICE

CALIFORNIA REGION

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COVER: Locating a dead tree group using aerial photos mounted on a stereo photo board and inspecting a dead tree in the group to determine the insects and pathogens present.

THE PEST DAMAGE INVENTORY: FINDINGS OF A TREE MORTALITY SURVEY ON THE ELDORADO NATIONAL FOREST

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SUMMARY

The Forest Insect and Disease Management Staff of the California Region has been developing a survey system called the Pest Damage Inventory (PDI) to provide sound estimates of pest-caused damage to be used in impact evaluation and in timber management. Results from the second of three field tests of the Pest Damage Inventory are presented to illustrate the type of information obtained. This test was made on eight townships of the Eldorado National Forest. A total of 9,689±2243 trees died during the survey year (May 1972 to April 1973), or about 0.11 trees per acre of forested land per year. More than 75 percent of the trees were killed by disease/insect complexes. Many combinations of diseases and insects were encountered, some frequently and other infrequently. The annosus root rot/fir engraver beetle complex was responsible for killing more trees than any other complex, and the annosus root rot/fir engraver beetle/dwarf mistletoe complex caused the most volume loss. The volume loss within the large-timber stands was much higher than the average for the entire survey area. Possible operational uses of the survey methods are discussed.

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INTRODUCTION AND CONCEPTS

Land managers, administrators, and pest control specialists need reliable estimates of the impact caused by insects and diseases in timber-producing and recreation forests. This need was well documented at a National Forest Service workshop in 1972 (1). The estimates are needed for assigning priority of cutting of forested lands, for predicting the effects of alternative silvicultural treatments to the stands, and for determining the priority of research and action programs on the forest insects and diseases.

FOREST PEST EVALUATION SYSTEM.

The Forest Insect and Disease Management Staff is currently developing a system for measuring and evaluating damage caused by insects and diseases. The aim of this Forest Pest Evaluation System is to provide estimates of damage caused by insects and diseases, and to use these estimates to evaluate the economic impacts of insects and diseases on the forest resource of the Region. The System will also provide input into the Region's decision-making and resource-planning models.

The System will consist of standardized data collection, data management and data analysis procedures that will fit a variety of pest damage evaluations. The standardized procedures will be applicable to evaluations of (1) damage on geographic units of any size, (2) damage caused by any pest species or pest complex, (3) damage to any tree species, and (4) endemic or epidemic damage of several types (mortality, growth loss or defoliation).

PEST DAMAGE INVENTORY.

The Forest Pest Evaluation System will be based upon field and statistical methods developed as part of the Pest Damage Inventory (PDI). The PDI, also under development, is a method for measuring pest-caused damage in California Forests.

The Pest Damage Inventory was field-tested on an area of about 10,000 acres of the Stanislaus in 1972, on 87,000 acres of the Eldorado National Forest in 1973 and on the entire timber-producing lands of the Stanislaus National Forest in 1974 (a gross area of about a million acres). This report describes the methods, early results, and implications of the inventory from the limited-scale Eldorado survey. Other reports, incorporating the results of the full-scale Stanislaus survey, will be issued later.

OBJECTIVES

There were three objectives of the Pest Damage Inventory on the Eldorado National Forest.

1. Measure the tree mortality within major forest types and stand classes for a one-year period (May 1972 to April 1973).

2. Identify the insects and diseases, separately or in combination, that were responsible for that mortality.

3. Identify the stand, site, and host conditions that were associated with that mortality.

This report deals primarily with objectives 1 and 2. A more complete discussion of results on objective 3 will be included in subsequent reports. Those reports will be based on data from both the Eldorado National Forest and Stanislaus National Forest surveys.

METHODS

The survey was conducted on eight townships of the Eldorado National Forest in Amador and El Dorado Counties on 87,000 acres. This area was selected because it contained a sample of the main forest types of the west-side Sierra Nevada, because it was predominantly National Forest land for which timber type maps were available, and because of its accessibility.

PHOTO PLOT SELECTION.

A stratified random-sampling procedure was used to select an aerial photo sample of the survey area. All flight lines and all photo centers on those flight lines needed to provide complete stereoscopic photographic coverage of the 8-township study area at a scale of 1/8000 were delineated on topographic maps. Each plot around a photo center was rectangular and covered 282 acres. The forest type of each possible photo was ascertained from overlays of type maps, and sample plots were drawn at random from within each type in proportion to the area occupied by each type. Eight photo plots were selected from the pine type, thirty-six from the mixed-conifer type, and seven from the red fir type. Forest type was defined as follows:

Pine: Stands that are composed of at least 80% ponderosa pine, Jeffrey pine, or incense-cedar in any combination.

Red Fir: Stands with at least 70% true fir and 50% red fir.

Mixed Conifer: Stands consisting of at least 50% commercial conifers, excluding mountain hemlock, western white pine, or lodgepole pine, not falling into either of the above classifications.

Photographs of each sample plot were taken with 75 percent overlap for stereo using 9-½″ wide Ektachrome MS film (type 2448), a Zeiss RMK camera with an 8-¼″ lens, HF3 or 4 haze filters, and an antivignetting filter.

PHOTO INTERPRETATION (PI).

The aerial photos were examined for dead tree groups as follows: Plot boundaries were delineated on the center photograph of each triplet and the plots were viewed in stereo at 4× to 8× magnification. Each tree or group of dead trees within the photo plot that appeared yellow-to-sorrel at the time of photography was encircled on the photograph. Such faded trees were considered to have died within the year prior to taking the photographs. For each dead tree group, the photo interpreter recorded the number of dead trees, and the species and size class of each dead tree. Three size classes were used: less than 50′, 50′ to 100′, greater than 100′.

GROUND CHECK PLOTS (GC).

A stratified random sample of photo-detected dead tree groups was selected for ground sampling; five tree groups were selected within each of the tree species/size class/forest type strata. A total of 113 dead tree groups (45 in the pine type, 42 in the mixed conifer, and 36 in the red fir) were selected and visited to gather data used in calculating estimates of tree mortality. These data included the number of trees in the group, the species and size of each tree in the group, and the year in which each tree died.

The year of death was estimated primarily from color and condition of the foliage, and the condition of the bark. In addition, stand, tree, and pest data were recorded for all trees that were found to have faded within the year prior to photography (May 1972 to April 1973). Trees were examined for pests in the following manner: crowns and upper boles were observed through binoculars, bark was removed from lower boles, and axe cuts were made at the root crown and in the uppermost roots. Pests which were present in each tree were recorded, and the most important found on all trees in the mortality group were included in the pest complex for that group. Only known tree-killing pests or conditions were listed in the pest complex, and these were listed only when symptoms and signs indicated that the pest had contributed to the death of the trees. For instance:

1. *Fomes annosus* was included when typical stain, decay, or conks were found on the tree or other trees in the same disease center, or when the presence of the fungus could be verified by incubating wood samples. Wood samples were collected and incubated whenever *Fomes annosus* was suspected but could not be confirmed by stain, typical decays or conks.

2. *Armillaria mellea* was included only when a dead oak was present on the site near enough to provide inoculum source or when symptoms and signs indicated that the fungus was present on the tree at the time of death. When both *A. mellea* and *F. annosus* were present, only *F. annosus* was listed.

3. Dwarf mistletoes were included in the pest complex when the rating of any tree was two or more using Hawksworth's 6-point system (4).

4. *Dendroctonus* spp., and *Scolytus ventralis* were listed as pests when their distinctive galleries indicated their presence and successful attack of the tree.

5. The roundheaded fir borer, *Tetropium abietis*, was listed in the pest complex only when *S. ventralis* was absent. However they did frequently infest the same trees.

STATISTICAL ANALYSIS:

The equation used to estimate the current mortality for a WRIS[1] stratum is:

$$N_{fgh} = \frac{A_h}{a_h} \bullet \frac{T_{gh}}{t_{gh}} \bullet \sum_{i=1}^{t_{gh}} N_{fghi}$$

Where:

h = WRIS stratum

g = Photo Stratum

f = Ground attribute

i = Ground group index i=1, 2, ...tghf

N = Number of trees

A_h = Total area in WRIS stratum h

a_h = Total area of the photo samples within WRIS stratum h

T_{gh} = Total number of tree groups sampled in WRIS stratum h in PI size-species class g

t_{gh} = Total number of tree groups found in WRIS stratum h in PI size-species g which were ground checked.

Σ = Summation of a class of observations.

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[1]WRIS (Wildland Resource Inventory System) is a mapping procedure used on the Forest. WRIS strata are based upon stand species composition, size class and stocking density. The strata that we used were timber type and stand condition class.

The equation used to estimate the variance (S^2) of a set of sample observations for a WRIS stratum is:

$$S^2(N_{fgh}) = C^2_{gh} \frac{1}{(t_{gh})(t_{gh}-1)} \sum_{i=1}^{t_{gh}} N^2_{fghi} - t_{gh} \hat{N}^2_{fgh}$$

Where:

$$\hat{N}_{fgh} = \frac{1}{t_{gh}} \sum_{i=1}^{t_{gh}} N_{fghi}$$

$$C_{gh} = \frac{A_h}{a_h} \bullet T_{gh}$$

The equation used to estimate cubic foot volume by WRIS strata is:

$$CV_h = \sum_{i=1}^{N_{fghi}} K \quad \frac{(D^2)\ (LH)}{100}$$

Where:

CV = Cubic foot volume

K = A constant

D = Tree DBH

LH = Tree log height in 16 foot logs.

The equation to estimate the reliability of a sample is:

$$CIN_{fgh} = S^2N_{fgh} \bullet t$$

Where:

CI = The confidence interval

t = The value from the t-table

The confidence limits were calculated at the 80% probability level.

The equation used to estimate variance over a number of WRIS strata is:

$$S^2N_f = \sum_{i=1}^{h} \sum_{i=1}^{g} [S^2{}_{fgh}\ (N_{fgh})]$$

RESULTS

Statistically valid estimates of the number of trees killed were obtained for the survey year (May 1972 to April 1973) within several strata: forest type, tree species, tree size class, and pest complex. Some of these estimates, and estimates of wood volumes contained in the dead trees, are presented in the following tables and figures. A short explanation follows each table.

TABLE 1. *Estimated tree mortality in pine, mixed conifer, and red fir types during the survey year.*

FOREST TYPE	DEAD TREES		VOLUMES	
	NO.	NO./ACRE	CUBIC FEET	CUBIC FT./ACRE
Pine	1246± 326	0.11±0.03	61,300±16,000	5.4±1.4
Mixed Conifer	6979±1595	0.11±0.03	96,500±22,300	1.6±0.4
Red Fir	1296± 358	0.11±0.03	41,000±11,800	3.5±1.0
All Types	9689±2243	0.11±0.03	198,800±46,000	2.4±0.5

The number of trees killed/acre/year (0.11) was similar over the three forest types and approximates the estimate of 0.14 from a smaller survey in 1972 done on the Stanislaus National Forest. Volume loss/acre varied by the type with the highest amount occurring in the pine type, the lowest in the mixed conifer.

TABLE 2. *Estimates of tree mortality in principal stand condition classes during the survey year.*

STAND CONDITION CLASS[1]	DEAD TREES		VOLUMES	
	NO.	NO./ACRE[2]	CUBIC FT.	CUBIC FT./ACRE
Overmature Sawtimber	2,800± 700	0.129±0.032	77,500± 19,800	5.67±1.44
Large Sawtimber (dbh 21''+, 180 yrs.) not decadent	1,700± 440	0.058±0.015	125,500± 32,500	3.74±0.97
Two Story Stands	1,450± 600	0.104±0.043	9,200± 4,100	0.45±0.20
Small Sawtimber (dbh 11''–20.9'')	2,000±1160	0.154±0.090	13,146± 6,600	0.85±0.43
All Stands	9,689±2243	0.11 ±0.009	198,800± 46,000	2.40±0.56

[1]Stand condition classes described broadly the condition and structure of stands, and are designed to be used in predicting potential treatments that could be applied to a stand, and to simplify management decision-making (2).

[2]These estimates are shown in order to demonstrate the information which can be obtained. Their accuracy is questionable because the condition class for each mortality group was determined from the ground, while the acreages of condition classes were obtained from type maps, resulting in some discrepancies. In subsequent reports, condition classes will be determined from type maps.

Tree mortality, as measured by dead trees/acre, was high in the overmature sawtimber stands, and the volume killed/acre was higher in these stands than in stands of smaller and younger trees. The volume/acre loss in the large sawtimber stands was high in comparison to the two-storied and smaller sawtimber stands even though the number/acre was lower. This indicates that the trees that died in the large sawtimber stands were of comparatively large size.

TABLE 3. *Estimated tree mortality of four coniferous species during the survey year.*

TREE SPECIES	NO. DEAD TREES	VOLUME (cubic feet)	VOLUME/TREE (cubic feet)
Ponderosa Pine	3,913±1,233	33,600±10,600	8.6 ± 2.7
Jeffrey Pine	265± 130	12,600± 6,200	47.5 ±23.4
White Fir	2,393± 473	81,100±15,200	33.9 ± 6.4
Red Fir	2,405± 823	69,900±23,700	29.06± 9.9
All Species	9,689±2,243	198,000±46,000	20.5 ± 4.7

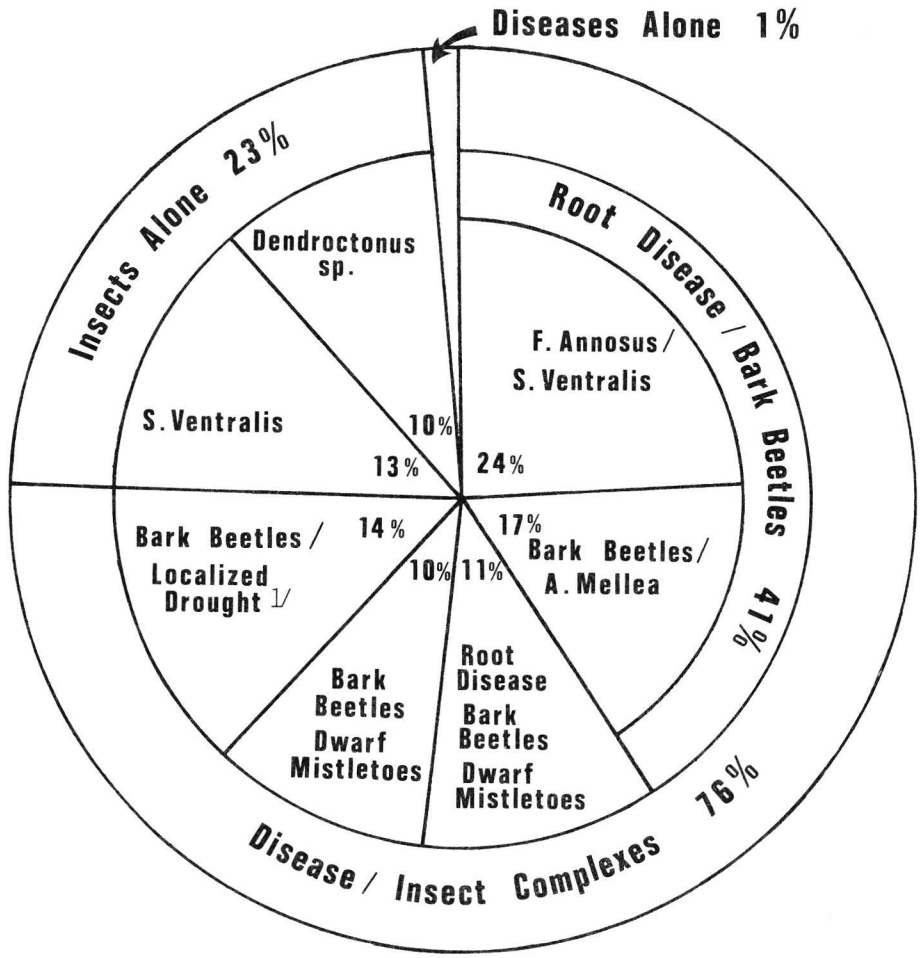
The ranking of loss by tree species from largest to smallest for number of trees is ponderosa pine, red fir, white fir and Jeffrey pine. Ranking by volume lost is white fir, red fir, ponderosa pine, Jeffrey pine. The average ponderosa pine killed was one fourth the volume of the average white fir indicating that many of the pines killed were small trees. A valid estimate of sugar pine mortality for the survey area was not obtained. Lodgepole pine, Douglas-fir, and incense-cedar were not sampled.

TABLE 4. *Pest species most frequently encountered, individually or as complexes, on dead pine and fir during the survey year.*

PEST SPECIES	NO. DEAD TREES	VOLUME (cubic feet)	VOLUME/TREES (cubic feet)
Scolytus ventralis	5,053± 970	141,900±27,200	28.1± 5.4
Dendroctonus brevicomis	2,887±1,327	32,300±14,900	11.2± 5.2
Fomes annosus	2,544± 683	97,400±26,100	38.3±10.3
Dendroctonus ponderosae	2,013±1,152	5,800± 3,350	2.9± 1.7
Arceuthobium spp.	1,861± 608	104,800±34,250	56.3±18.4
Total Mortality	9,689±2,243	198,800±46,000	20.5± 4.7

The ranking of the pests in order of largest to smallest number of trees killed is *S. ventralis, D. brevicomis, F. annosus, D. ponderosae,* and *Arceuthobium* spp. The ranking based on volume killed is *S. ventralis, Arceuthobium* spp., *F. annosus, D. brevicomis* and *D. ponderosae*. The two pathogens were associated with the largest trees, the dendroctonus beetles the smallest.

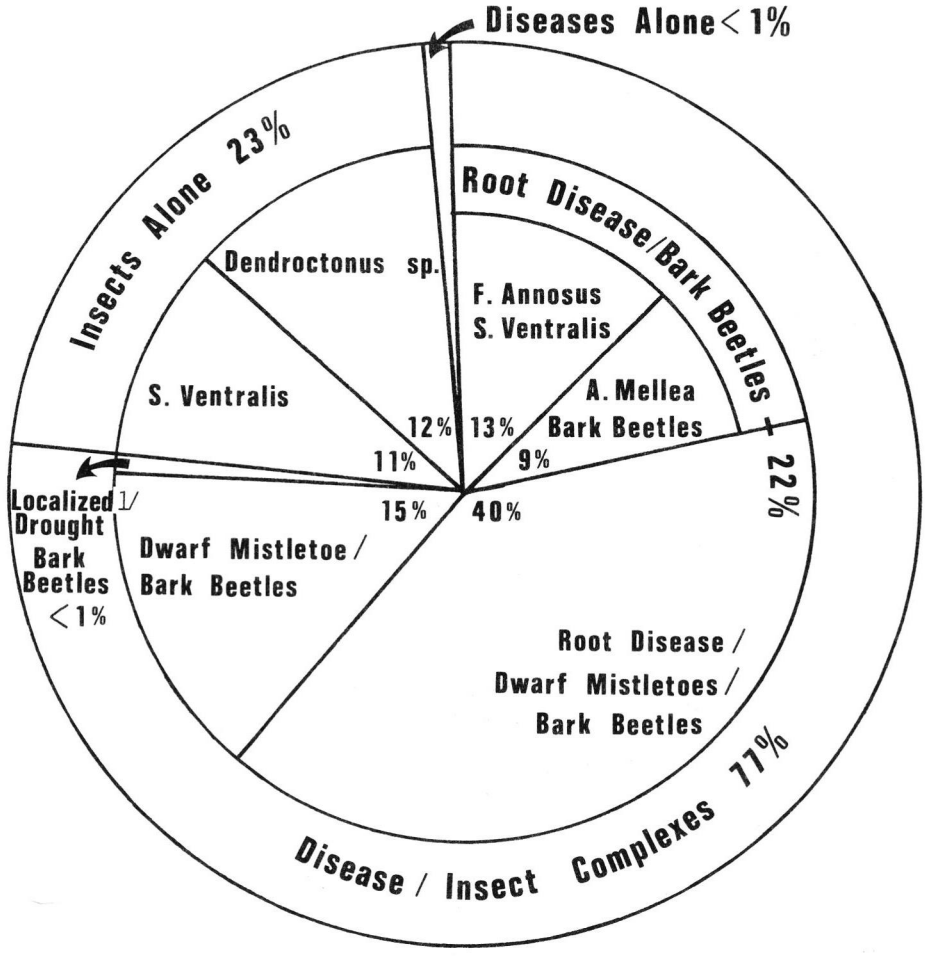
FIGURE 1. *The percentages of sample trees killed by individual diseases, insects, and disease/insect complexes.*



[1]The term "localized drought" is used to describe mortality occurring on a dry site.

Results for all tree species for the entire study area show that disease/insect complexes accounted for about three-fourths of the tree mortality. Insects alone accounted for most of the remainder. The number of dead sample trees not infested by one or more species of insects was less than one percent. The root disease/bark beetle complexes were responsible for 41 percent of the total mortality, and for 52 percent when dwarf mistletoe was included with the complexes.

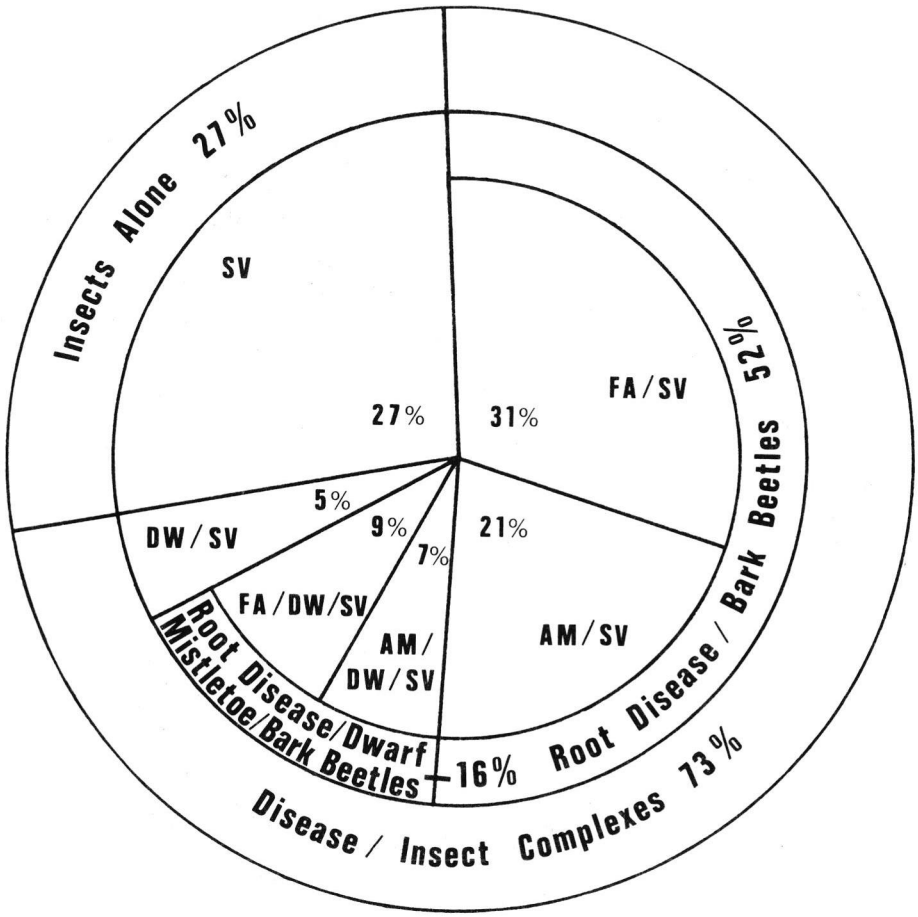
FIGURE 2. *The percentage of the total volume of sample trees killed by individual diseases, insects, and disease/insect complexes.*



[1]The term "localized drought" is used to describe mortality occurring on a dry site.

The trees killed by disease/insect complexes accounted for more than three-fourths of the volume; insects alone accounted for most of the remainder. A comparison of Figures 1 and 2 shows that the trees killed by the root disease/dwarf mistletoe/bark beetle complexes were disproportionately large; these complexes accounted for 11 percent of the tree numbers, and 40 percent of the volume. The trees killed by the localized drought/bark beetle complexes were disproportionately small; they accounted for 14 percent of the total tree numbers and less than one percent of the volume.

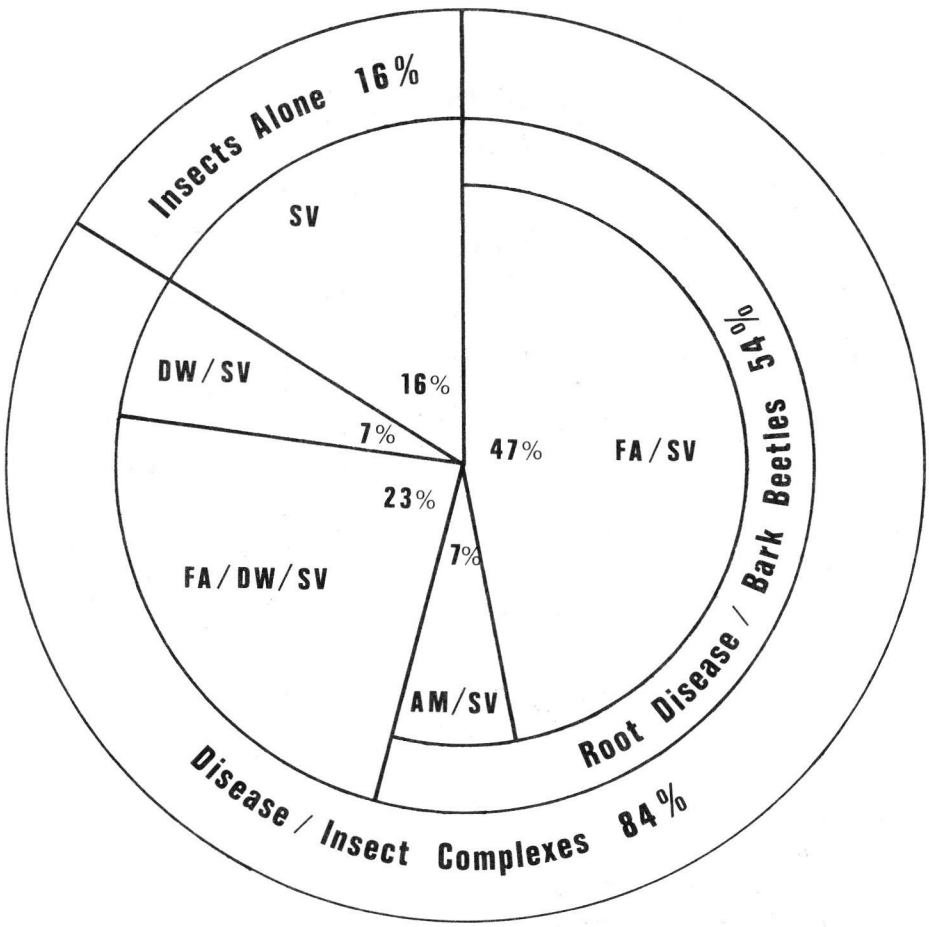
FIGURE 3. *The percentages of sample white fir trees killed by individual diseases, insects, and disease/insect complexes.*



SV = *Scolytus ventralis*.
DW = *Arceuthobium abietinum* f. sp. *concoloris*.
FA = *Fomes annosus*.
AM = *Armillaria mellea*.

The root disease/bark beetle complexes and the root disease/dwarf mistletoe complexes accounted for about two-thirds of the mortality. Both *A. mellea* and *F. annosus* appeared important on white fir. *S. ventralis* was the only mortality agent found on 27 percent of the trees.

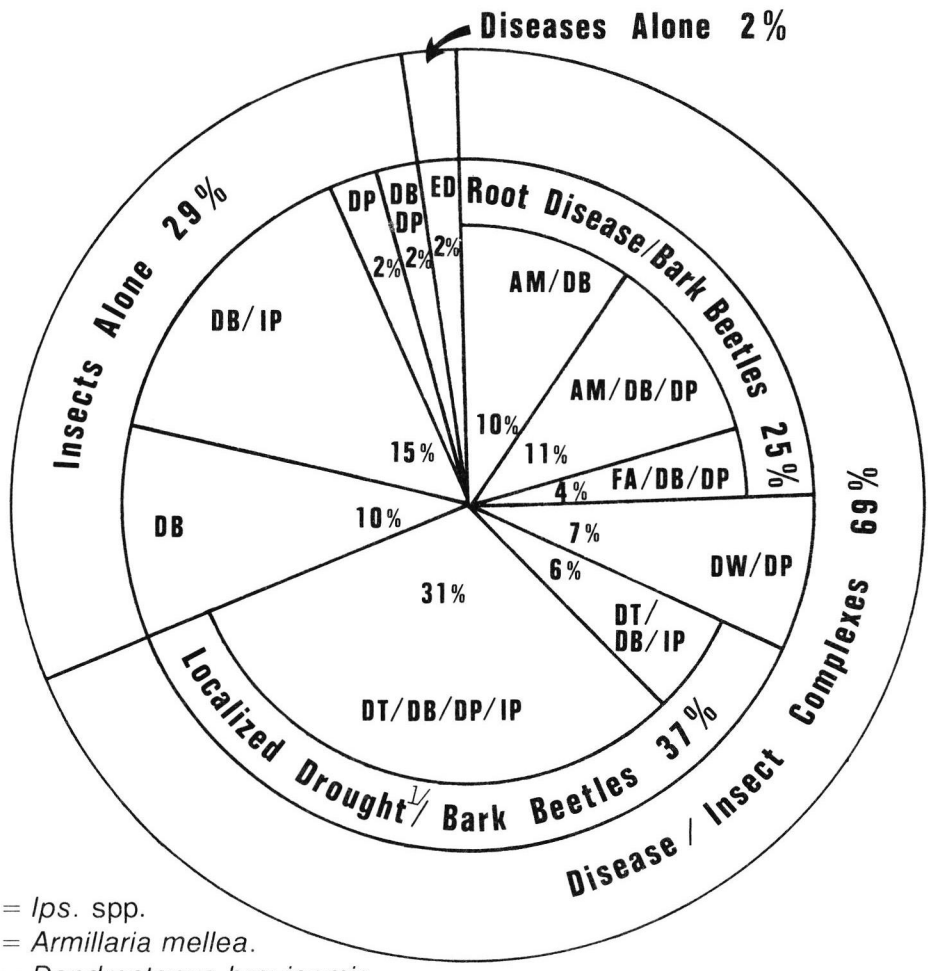
FIGURE 4. *The percentages of sample red fir trees killed by individual diseases, insects, and disease/insect complexes.*



SV = *Scolytus ventralis*.
DW = *Arceuthobium abietinum* f. sp. *magnificae*.
FA = *Fomes annosus*.
AM = *Armillaria mellea*.

The *F. annosus/S. ventralis* complex was associated with 70 percent of the dead trees. *S. ventralis* alone was detected in 16 percent.

FIGURE 5. *The percentages of sample ponderosa pine trees killed by individual diseases, insects, and disease/insect complexes.*



IP = *Ips*. spp.
AM = *Armillaria mellea*.
DB = *Dendroctonus brevicomis*.
DP = *Dendroctonus ponderosae*.
DW = *Arceuthobium campylopodum*.
ED = *Elytroderma deformans*.
FA = *Fomes annosus*.
DT = Localized drought.

[1]The term "localized drought" is used to describe mortality occurring on a dry site.

Seventy percent of the trees were killed by disease/insect complexes; *A. mellea*, dwarf mistletoe, and drought were the most important diseases, and *D. brevicomis* and *D. ponderosae* were the most important insects. Trees infested by *D. brevicomis* were also infested frequently by *D. ponderosae* or *Ips* spp. Only five dead Jeffrey pine were sampled for pests. The *Arceuthobium campylopodum/Dendroctonus jeffreyi* complex killed four of these; *A. campylopodum/Ips* sp. killed the other.

DISCUSSION

Estimates of tree mortality valid at the 80% confidence level were obtained for major stand types, stand condition classes, tree species and pest complexes in the survey area for the survey year (May 1972 to April 1973).

Dead trees and groups that were not detected during photo interpretation were not included in the mortality estimate. However, subsequent ground checks, made as a part of the 1974 survey, revealed that undetected trees were mostly smaller, overtopped trees less than 50′ tall. These small trees which were missed contained relatively little volume and were generally unmerchantable. Results from the 1974 survey indicate that only a small percentage of trees larger than 50′ tall were missed.

PEST COMPLEXES.

The results obtained from the survey substantiate the concept of pest complexes, i.e., two or more disease-causing agents and/or insect species which act jointly to kill the tree. Pest complex, as used here refers to disease/insect complexes, insect complexes and disease complexes.

More than 75 percent of the trees and volume were killed by disease/insect complexes. Research results in California indicate that insect/disease complexes in endemic situations are responsible for much tree mortality in other parts of California. Examples are: *F. annosus/S. ventralis* (3), *Phorondendron bolleanum* (true fir mistletoe)/*S. ventralis* (4), Photochemical oxidants/*Dendroctonus brevicomis* (6), *Verticicladiella wagenerii/D. brevicomis* (3), and *F. annosus/D. brevicomis* (3).

About 25 percent of the trees and of the volume were killed by insect species; no pathogens were detected. Insect complexes consisting of two or more species accounted for about 10 percent of the tree mortality and five percent of the volume loss; a single insect species was present in about 15 percent of the trees accounting for 20 percent of the volume.

Our results indicate that *F. annosus* was the most serious pathogen in the study area. In combination with dwarf mistletoe and *S. ventralis, F. annosus* was responsible for nearly 40 percent of the tree mortality and 50 percent of the volume loss. We believe this estimate is conservative. Research results (Parmeter, personal communication) show that the roots of many firs killed by *S. ventralis* are severely decayed by *F. annosus* prior to the death of the tree even though there are no above-ground symptoms or signs of *F. annosus* in the disease center. For this reason we suspect that *F. annosus* contributed to the death of some red and white firs that were attributed to *A. mellea/S. ventralis* and *S. ventralis* alone. Cobb, et al (3) found that 97 percent and 79 percent of the *S. ventralis*-killed white fir in stands in two other locations on the Eldorado National Forest were infected by *F. annosus*. Parmeter (person communication) has comparable research results from

white fir on the Stanislaus National Forest and elsewhere in California. Dwarf mistletoes were associated with a large proportion of the red and white fir mortality.

Our evidence indicates that the dwarf mistletoes were contributing to the death of most of the large, over-mature fir growing in dense stands. Scharpf and MacGregor (unpublished data) found that moderate infections of dwarf mistletoes have little effect on the growth of released red fir trees. Fir dwarf mistletoes apparently have less effect on trees in young, managed stands, but effects will increase with stand age.

MANAGEMENT APPLICATIONS.

A major objective of the inventory, if it becomes operational in timber-producing forests, will be to identify high-loss stands for first priority harvest as well as to identify those in which treatments can be deferred. Results from this survey indicate that the greatest volume loss of standing timber is taking place in overmature saw-timber-size stands in the mixed-confier and red fir types and in large saw-timber-sized stands in the pine type on the Eldorado National Forest.

The greatest tree and volume loss per acre occurred in the overmature saw-timber stands (decadent stands past rotation age). Many of these stands were in the red fir type which accounts for the relatively large volume/acre estimate in Table 1. The loss (5.67ft^3/acre: Table 2) due to tree mortality in large timber stands represents about 6 percent of the annual growth of those stands. Nearly all of this lost volume was in large red and white fir trees; most was caused by the *F. annosus/S. ventralis*/dwarf mistletoe complex.

The number of trees killed per acre in the medium timber-size class was low, but the volume killed/acre was above average since the trees were large. Medium timber stands having above-average volume loss were primarily in the pine type (Table 1). Most of the dead trees were ponderosa pine located in stands or locations within stands where the basal area was high (400 to 480 ft^2/acre). *D. brevicomis* was the immediate cause of death of most of those trees.

Volume loss of standing timber was low in the two-story and small timber stands, indicating that the priority for cutting these is low from the standpoint of mortality. However, annual timber yields may be reduced by pest-caused mortality and growth loss. Most of the trees killed in these stand size classes were true firs killed by the *F. annosus/S. ventralis* pest complex. This complex could become increasingly important in the management of young-growth fir stands.

There were two few acres of pole-sized stands and too few dead trees in those stands to give a valid estimate of mortality. The mortality that did occur in this stand class was due to drought/bark beetle complexes. Here, small trees were dying on harsh, dry sites that were not suitable for growing commercial timber.

CONCLUSIONS

The following conclusions are based on this limited-scale test made on the Eldorado National Forest.

1. The aerial photo-ground sampling method gives statistically acceptable estimates of current mortality of trees taller than 50 feet for major strata and classes (timber types, stand condition classes, tree species, and pest species). Good estimates of smaller trees may be obtained, if they are in the dominant and codominant crown classes. Use of the methods for surveying even-aged plantations should be tested.
2. The results indicate that the method is applicable to large geographic areas, up to about 100,000 acres of timbered land. Conclusions regarding its applicability to even larger areas will be made following the analysis of the data from the full-scale test on the Stanislaus National Forest but preliminary results using Stanislaus National Forest data are encouraging.
3. Most of the trees were killed by a pest complex, rather than by a single pest species. The approach used here (measuring the damage caused by all pests in one survey and expressing damage caused by a pest complex as a part of the whole) is preferred over individual surveys for specific pest species under such conditions. This method accounts for the complex cause of tree death.

IMPLICATIONS

Based on test results, the method appears to be applicable to making large-scale biological evaluations where a statistically valid measure of tree mortality is needed in a short time. The Staff is using it for large biological evaluations currently in progress.

The use of efficient and reliable sampling procedures make possible rapid data collection over large areas. Standardized data forms make the method adaptable to a variety of situations. And since programs for data management and analysis have been developed, the time and cost of producing damage summaries have been shortened considerably.

It also appears that the Pest Damage Inventory could be a companion survey to the Timber Inventory, which provides the resource information on which the timber management plans for each National Forest are based. Briefly stated, the Timber Inventory gathers data on timber yield within stand condition classes. These classes reflect stocking, growth, species, and age composition, and prior silvicultural treatment. Yield data are used to calculate allowable harvest rates and cutting schedules.

The Pest Damage Inventory measures pest-related damage by the same stand condition classes as the Timber Inventory, providing estimates of mortality. Growth-loss data could be gathered for selected classes during future inventories. These mortality and growth loss estimates could be used with the yield estimates of the Timber Inventory in setting harvest priorities and arriving at silvicultural prescriptions for the forest.

If used systematically on the Forests of the Region, the Pest Damage Inventory would also provide a data base on pest-caused effects that can be used in impact evaluation. The accumulated data from the National Forests over a period of years would permit the calculation of Regionwide damage caused by each of the important forest insects, pathogens, and pest complexes.

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